



US009257937B2

(12) **United States Patent**
Vaidyanathan

(10) **Patent No.:** **US 9,257,937 B2**
(45) **Date of Patent:** ***Feb. 9, 2016**

(54) **MINIMAL PENETRATION MODULAR
ROOF-TOP MOUNTING RACKS AND SOLAR
PHOTOVOLTAIC SYSTEMS
INCORPORATING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

This patent is subject to a terminal dis-
claimer.

(21) Appl. No.: **14/480,275**

(22) Filed: **Sep. 8, 2014**

(65) **Prior Publication Data**

US 2015/0059834 A1 Mar. 5, 2015

Related U.S. Application Data

(63) Continuation of application No. 14/043,569, filed on
Oct. 1, 2013, now Pat. No. 8,826,608.

(60) Provisional application No. 61/708,675, filed on Oct.
2, 2012.

(51) **Int. Cl.**

E04D 13/18 (2014.01)

E04H 14/00 (2006.01)

H02S 20/23 (2014.01)

F24J 2/52 (2006.01)

H01M 10/46 (2006.01)

H02J 7/35 (2006.01)

F24J 2/54 (2006.01)

(52) **U.S. Cl.**

CPC **H02S 20/23** (2014.12); **F24J 2/5205**

(2013.01); **F24J 2/526** (2013.01); **F24J 2/5245**
(2013.01); **H01M 10/465** (2013.01); **H02J**
7/355 (2013.01); **F24J 2002/5292** (2013.01);
F24J 2002/5486 (2013.01); **Y02B 10/12**
(2013.01); **Y02B 10/14** (2013.01); **Y02B 10/20**
(2013.01); **Y02E 10/47** (2013.01)

(58) **Field of Classification Search**

CPC H02S 20/23; F24J 2/5205; F24J 2/5245;
F24J 2/526; F24J 2002/5292; F24J 2005/5486;
H01M 10/465; H02J 7/355; Y02B 10/12;
Y02B 10/14; Y02B 10/20; Y02E 10/47
USPC 52/173.3, 653.1; 182/45; 136/245
See application file for complete search history.

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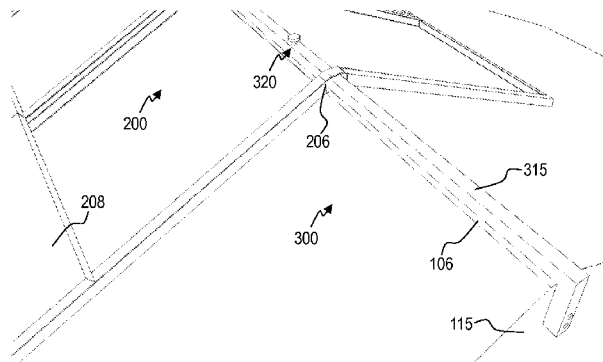
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(57) **ABSTRACT**

The present invention provides for a modular, plug-and-play
DC/AC compatible solar photovoltaic power system and
mounting frames therefor, having inexpensive modular
designs which require no or minimal penetration for rooftop
installation and provide enhanced wind-induced position dis-
ruption protection.

20 Claims, 6 Drawing Sheets



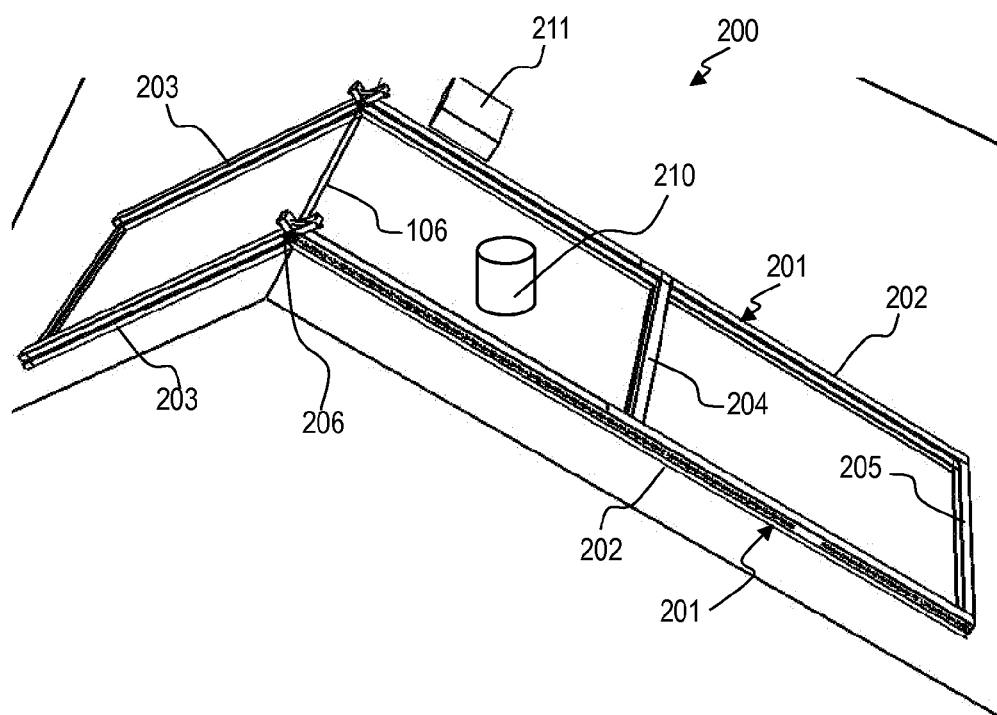
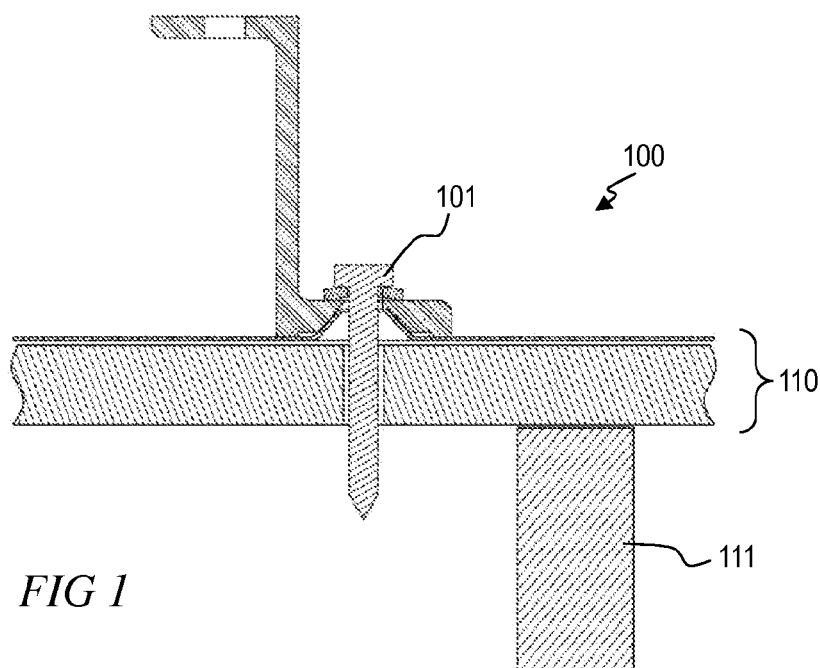
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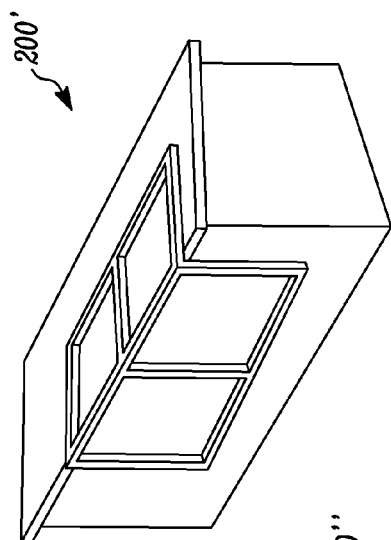


FIG. 2A'

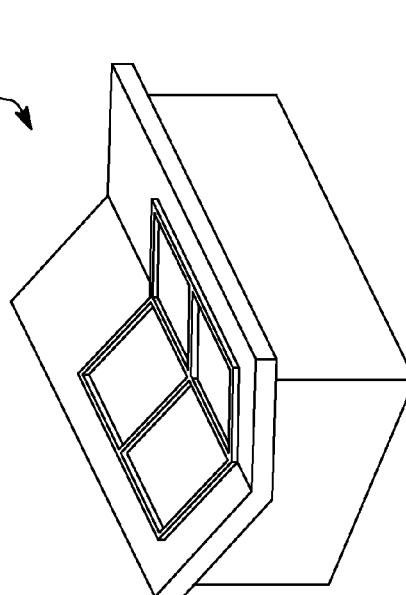


FIG. 2A'''

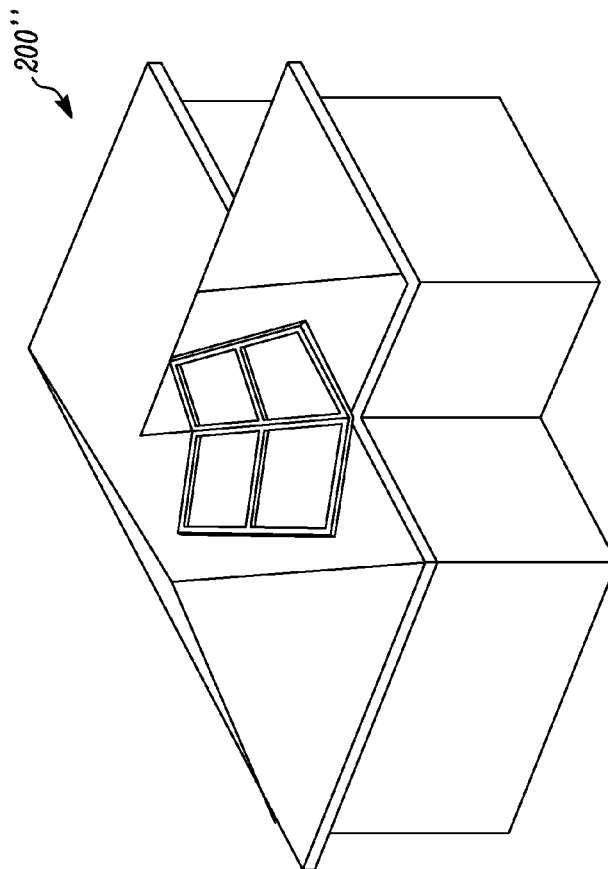


FIG. 2A''

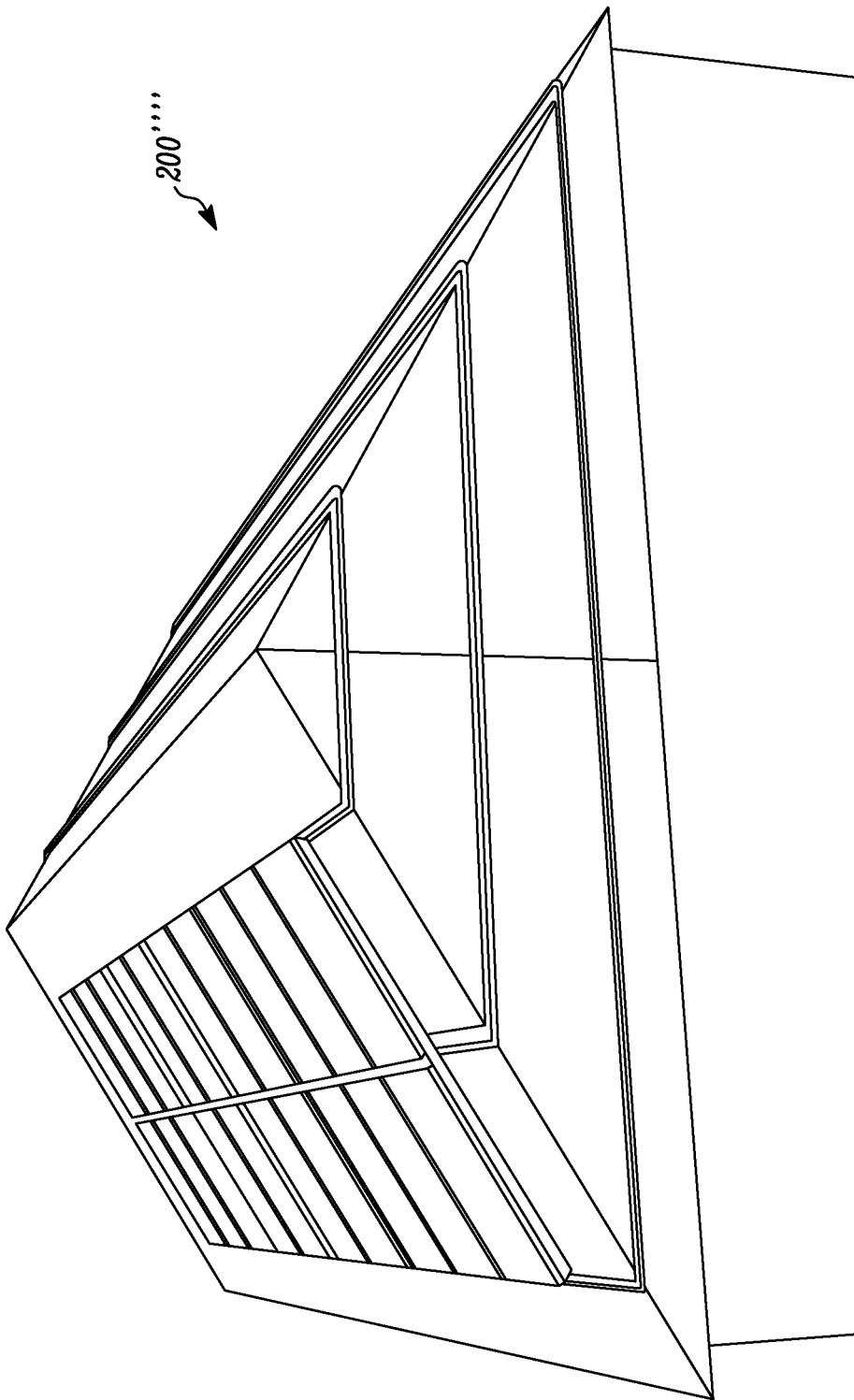


FIG. 2A'''

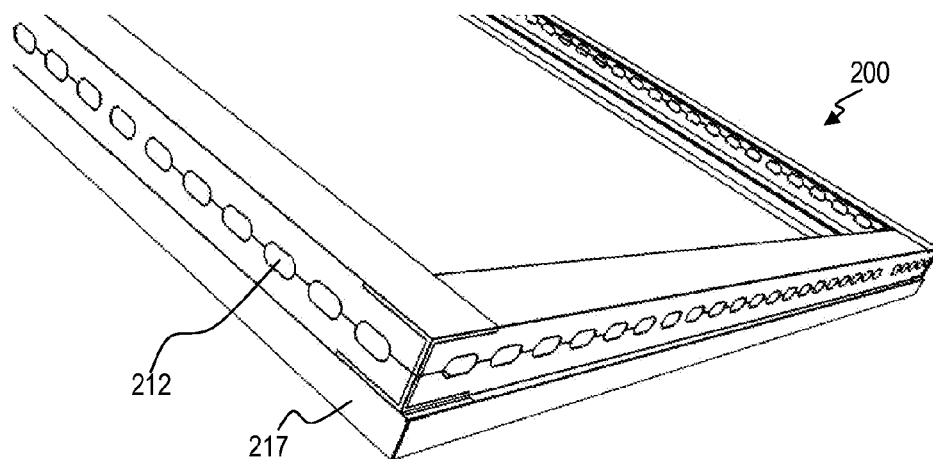


FIG 2B

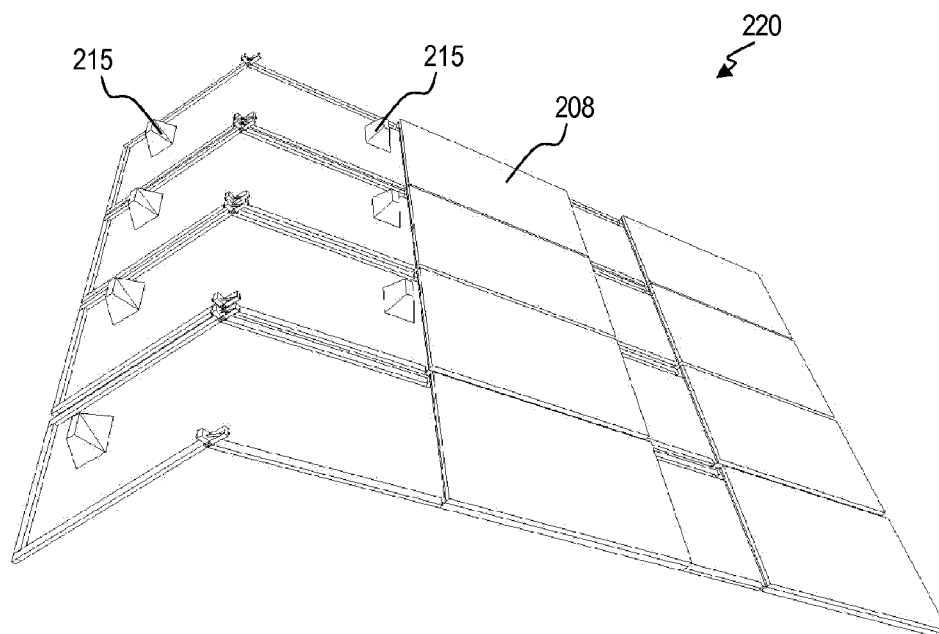


FIG 2C

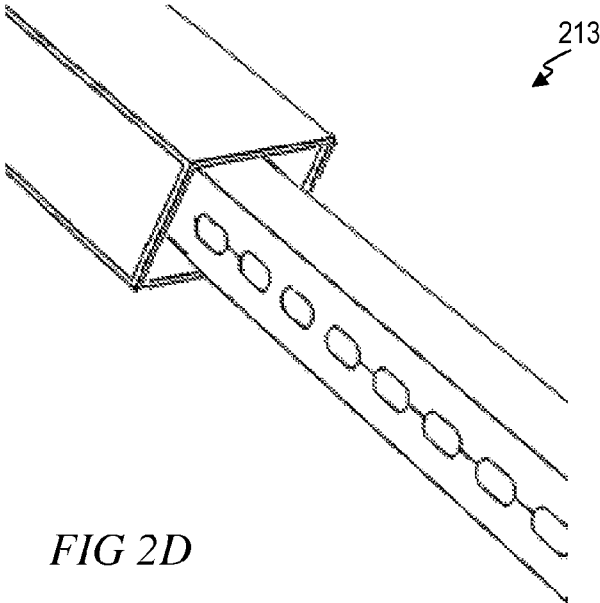


FIG 2D

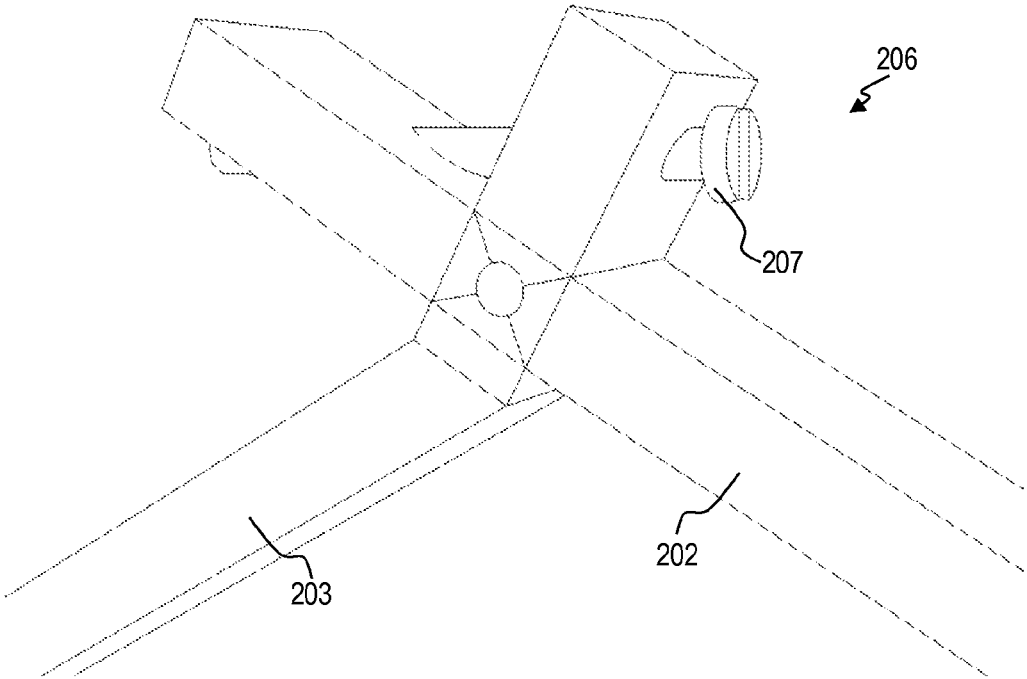
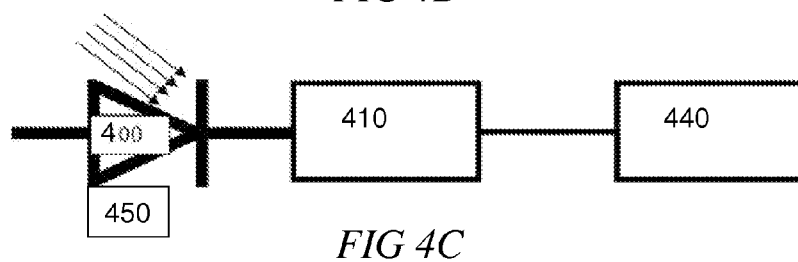
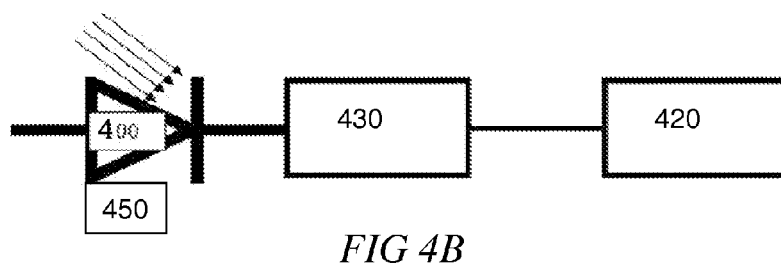
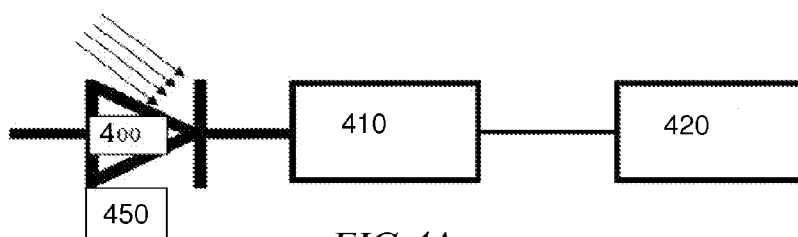
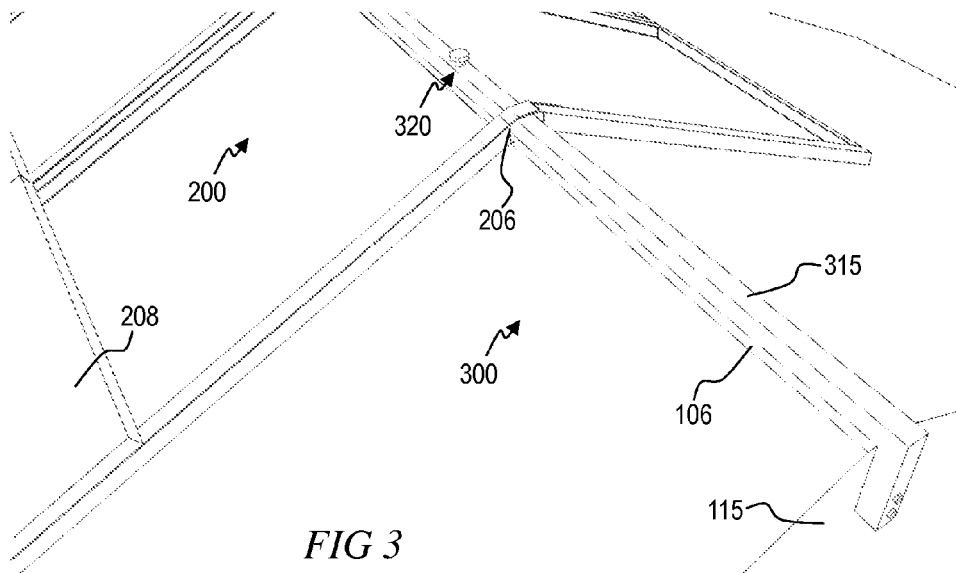


FIG 2E



MINIMAL PENETRATION MODULAR ROOF-TOP MOUNTING RACKS AND SOLAR PHOTOVOLTAIC SYSTEMS INCORPORATING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. application Ser. No. 14/043,569, filed on 1 Oct. 2013, which claims priority under 35 U.S.C. §119(e) to U.S. Provisional Patent Application No. 61/708,675, filed on 2 Oct. 2012, the contents of which are incorporated herein by reference in their entirety. A claim of priority is made.

BACKGROUND

Electrical power generation units, for example renewable energy systems such as solar photovoltaic systems, may be connected to an electrical utility grid or act as stand-alone power generation units and have become popular with home and business owners. It is common for customers to purchase solar photovoltaic systems for both purposes, such systems being most commonly installed on rooftops. Basic roof top solar photovoltaic systems involve one or more standardized solar panels which are attached to or integrated with mounting racks. Solar photovoltaic systems, including the solar photovoltaic panels, inverter, and mounting racks are designed and installed by providers, and typically must be customized for particular customers. The number of panels per system, electrical connections between individual panels, power-consuming devices, and the electric utility grid, zoning conditions, and installation site accessibility, among other factors, can significantly increase system prices.

Roof installation involves anchoring the system at a number of points throughout, requiring penetration at a number of anchor points. Each anchoring point **100**, such as the one shown in FIG. **1**, typically employs a lag bolt **101** or similar fastening element which penetrates all layers of the roof **110**, which may include shingles, tar or felt paper, ice guard, the roof deck, flashing, and ridge caps, decreasing the sealing integrity of the roof. Anchoring point fasteners ideally, and often must, further penetrate roof rafters or trusses **111** for added strength against high winds and other elements, further increasing installation costs.

Further, roof construction, replacement, and overall life spans will not necessarily coincide with a solar photovoltaic system installation's lifespan, or a roof may become damaged by hail, falling trees or other like occurrences that will necessitate replacement or repair of the roof. In the event of such occurrences, roof-penetrating anchoring systems may need to be uninstalled and reinstalled a number of times, thereby detrimentally affecting overall system economics.

SUMMARY

Embodiments of the invention relate to modular roof-top mounting frames which require minimal or no penetration for rooftop installation and are capable of accepting solar panels or may be integrated into plug-and-play solar photovoltaic systems. Mounting frames may comprise a plurality of hinged brackets each having a first arm and a second arm connected at hinge point. When the plurality of hinged brackets are aligned or connected, the plurality of first arms align to substantially form a first plane and the plurality of second arms align to substantially form a second plane. One or more photovoltaic solar panels may be mounted throughout the first

plane, throughout the second plane, or throughout both the first plane and throughout the second plane.

Solar photovoltaic systems which incorporate various embodiments of mounting frames described herein may further comprise one or more solar panels, an electrical power generation unit, a power inverter, and a power outlet, which may be connectable to energy storage units, electrically-powered devices, or an electric utility grid.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate non-limiting example embodiments of the invention.

FIG. **1** is a cross-sectional side view of a roof-penetrating anchor, according to the prior art.

FIGS. **2A-2A'''** show perspective views of modular mounting frames positioned at a roof line.

FIG. **2B** is a perspective view of a mounting frame having holes spaced throughout its arms and end caps.

FIG. **2C** is a perspective view of a mounting frame equipped with a plurality of solar panels and mounting weights.

FIG. **2D** is a perspective view of an adjustable arm, according to some embodiments.

FIG. **2E** is a perspective view of an adjustable and lockable hinge, according to some embodiments.

FIG. **3** is a perspective view of gable-penetrating mounting frame, according to some embodiments.

FIG. **4A** is a schematic view of a solar photovoltaic power generator connected to a power source meter and switch, and a utility grid.

FIG. **4B** is a schematic view of a solar photovoltaic power generator connected to an energy storage system and a utility grid.

FIG. **4C** is a schematic view of a solar photovoltaic power generator connected to a power source meter and switch, and a secondary power generator.

DETAILED DESCRIPTION

Embodiments of the invention relate to modular roof-top mounting frames which require minimal or no penetration for rooftop installation and are capable of accepting solar panels or may be integrated into plug-and-play solar photovoltaic systems. Mounting frames may comprise a plurality of hinged brackets each having a first arm and a second arm connected at hinge point. When the plurality of hinged brackets are aligned or connected, the plurality of first arms align to substantially form a first plane and the plurality of second arms align to substantially form a second plane. One or more photovoltaic solar panels may be mounted throughout the first plane, throughout the second plane, or throughout both the first plane and throughout the second plane.

Solar photovoltaic systems which incorporate various embodiments of mounting frames described herein may further comprise one or more solar panels, an electrical power generation unit, a power inverter, and a power outlet, which may be connectable to energy storage units, electrically-powered devices, or an electric utility grid.

Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail in order to avoid unnecessarily obscuring the invention. The drawings show, by way of illustration, specific embodiments in which the invention may be practiced. These embodiments may be com-

combined, other elements may be utilized or structural or logical changes may be made without departing from the scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

All publications, patents and patent documents referred to in this document are incorporated by reference herein in their entirety, as though individually incorporated by reference. In the event of inconsistent usages between this document and those documents so incorporated by reference, the usage in the incorporated references should be considered supplementary to that of this document; for irreconcilable inconsistencies, the usage in this document controls.

In this document, the terms “a” or “an” are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of “at least one” or “one or more”. In this document, the term “or” is used to refer to a nonexclusive or, such that “A, B or C” includes “A only”, “B only”, “C only”, “A and B”, “B and C”, “A and C”, and “A, B and C”, unless otherwise indicated. The terms “above” and “below” are used to describe two different directions in relation to the center of a composite and the terms “upper” and “lower” may be used to describe two different surfaces of a composite. In the appended aspects or claims, the terms “first”, “second” and “third”, etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

The term “about” can refer to a variation of $\pm 5\%$, $\pm 10\%$, $\pm 20\%$, or $\pm 25\%$ of the value specified. For example, “about 50” percent can in some embodiments carry a variation from 45 to 55 percent. For integer ranges, the term “about” can include one or two integers greater than and/or less than a recited integer at each end of the range.

Mounting frames as described herein may refer to stand-alone frames or integrated components of solar photovoltaic power systems. FIG. 2A depicts a basic modular mounting frame **200**, comprising two hinged brackets **201**. Each bracket has a first arm **202** and a second arm **203**, connected by a hinge **206**. Hinges **206** may be adjusted on-site and locked into position so as to place a compression load on a rooftop. FIG. 2E shows a zoomed-in view of hinge **206**, and bolt **207** used for adjusting and locking the hinge **207** according to some embodiments. Adjustable hinges allow the system to be adjusted for irregular rooftop surfaces, marginal differences in shingle thickness, and other non-uniformities. In some embodiments the first arm **202** and second arm **203** are connected via welding or other immovable mechanical means such as bolts. Embodiments may also include perpendicular cross beams **204** and end caps **205**, as shown in FIG. 2A, to enhance the structural integrity, provide additional mounting surface for solar panels, or to provide wind-blocking protection. Perpendicular cross beams may be positioned anywhere throughout the lengths of the first arms **202** or second arms **203**, and may also connect at the hinges **206**. The hinges **206** or connection points of each bracket are positioned proximate to a roof line **106** as shown in FIG. 2A, and maintained in position by the weight of the mounting frame or overall solar photovoltaic system. A roof line may be a roof peak, a roof valley, or a roof edge. FIG. 2A' shows a mounting frame **200'** positioned at a roof edge. FIG. 2A'' shows a mounting frame **200''** positioned at a roof valley. FIG. 2A''' shows a mounting frame **200'''** positioned at a roof valley. FIG. 2A'''' shows a mounting frame **200''''** positioned at a roof edge.

When multiple hinged brackets are combined, the two first arms align to substantially form a plane, on which solar panels may be mounted. The second arms align to substantially form a plane, on which solar panels may also be mounted. One or more solar panels may be mounted on the

first plane, on the second plane, or on both planes. Mounting frames will often contain solar panels on the first plane, or the second plane, depending on the orientation to the sun. The first arms and second arms may be lengthened or shortened to accommodate for more or larger solar panels, available rooftop space, rooftop shape, or ballasting concerns. FIG. 2D shows an embodiment of an adjustable arm **213**. All first arms need not be the same length, and all second arms need not be the same length. For example, a particular mounting frame may have 4 hinged brackets, wherein two adjacent first arms are each 10 feet long and two adjacent first arms are each 15 feet long. In this particular example embodiment, the second arms may be any length, for example 5 feet. Similarly, first arms and second arms need not be the same length, as shown in FIG. 2A.

The embodiments disclosed herein may be advantageously mounted to a rooftop without penetrating any layers of the roof, thereby avoiding damage to the rooftop and minimizing installation costs. Adhesive **217**, as shown in FIG. 2B, may be used to secure the mounting frame to a rooftop, and also prevent wind flow between the mounting frame and the roof, or between the roof and any solar panels attached to or integrated with the mounting frame. In some embodiments, the adhesive **217** will have a coefficient of thermal expansion value between the coefficient of thermal expansion of the contacting roof surface and the coefficient of thermal expansion of the contacting mounting frame surface. In some embodiments the adhesive **217** is butyl rubber.

A modular design allows for a plurality of hinged brackets to be incorporated in a solar mounting frame **220**, as shown in FIG. 2C. Additional hinged brackets may be added based on roof size, solar panel **208** size, structural integrity, or other concerns. The modular design also allows for quick customization of a solar photovoltaic system to any roof. For example, rooftop obstructions such as vent pipes **210**, skylights **211**, chimneys, or the like, may be easily avoided, as shown in FIG. 2A. Additionally, orientation of solar panels to the sun is a critical factor in power generation. The modular no-penetration and minimal-penetration systems described herein allow for versatile and easily customizable solar photovoltaic power systems to be efficiently oriented and installed to maximize power generation. The modular and no-penetration and minimal-penetration designs additionally allow for simple, cost-effective system modifications relating to power generation optimization.

Arm length may also be adjusted for ballasting concerns. The first arms, the second arms, or both the first arms and the second arms may act as ballasting arms. The arms may also be weighted to accomplish ballasting of the mounting frame. For example, where a roof gable is shallow (i.e. about 15 degrees), longer arms are required to ballast the mounting frame. Conversely, a steeper gable (i.e. about 45 degrees) will require a shorter ballasting arm. If rooftop space, rooftop shape, aesthetic concerns, or other considerations limit the length to which a ballasting arm may be extended, the ballasting arm may be weighted to compensate for any deficiency in length. Weights **215** may also be added for further stability, as shown in FIG. 2C, even where no deficiency in ballasting arm length exists. Weights may be attached directly to any part of the mounting frame, or extended between the arms. For example, increased panel weight on the first plane may require additional ballasting weight on the second plane, increased length of second arms, or a combination thereof. Weights **215** may be incorporated anywhere throughout a mounting frame, as needed for ballasting.

High winds can disrupt the position of a mounting frame on a roof, particularly when a large number of solar panels are

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attached thereon, or a high amount of solar panel surface area is present. For example, for a mounting frame or solar photovoltaic power system positioned on a two-plane roof, or a roof with a peak edge oriented from East to West, a high wind in a North-to-South direction will create a high pressure area on the North side and a low pressure area on the South side. The pressure differential will cause the mounting frame to change positions or even lift entirely off the rooftop.

Embodiments of the mounting frame described herein provide a number of features to prevent wind-induced position disruption, such as the sealing adhesive, wind-blocking end caps, and customizable ballasting features as described above. Some embodiments further comprise a plurality of holes or openings **212**, as shown in FIG. 2B. When mounting frames are integrated with solar photovoltaic power generating components, such as a power inverter, it may become necessary to provide ventilation such that necessary components are maintained at suitable temperatures or pressures. For example, a power inverter may need to be kept at ambient temperatures. Openings or holes spaced through one or more of the first arms, second arms, perpendicular cross beams, end caps, or combinations thereof reduce wind velocity to acceptable levels between the mounting frame, solar panels, or other system components while providing adequate ventilation, pressure release, or both. Acceptable levels or velocity are those that do not create lift sufficient to disrupt the position of a mounting frame. For example, a highly-ballasted mounting frame with lower solar panel surface area would have a higher acceptable wind velocity than a lesser-ballasted mounting frame with higher solar panel surface area. After careful review of the disclosure herein, one of skill in the art shall be enabled to customize a mounting frame for any particular purpose. For example, a solar photovoltaic power system operating in a high-wind, high-heat environment on a shallow roof gable may require, for example, many holes or openings throughout the hinged brackets, long first and second arms, and ballast weights. In other embodiments, holes or opening sizes may differ between various arms, perpendicular cross beams, and end caps. For example, a mounting frame having four hinged brackets may have larger holes on the inner arms and small holes on the outer arms.

In other embodiments, as shown in FIG. 3, a gable-penetrating mounting frame **300** can comprise a gable-mounted pivot-bar **315**. The pivot-bar **315** would run substantially parallel to the roof line **106**, with each end being mounted to opposing gables **115**. The pivot-bar **315** would be rotatably attached to the mounting frame **200** at or near the plurality of hinges or arm connection points **206**, thereby providing enhanced wind-induced position disruption protection, without penetration of the rooftop. One or more roof-penetrating anchoring points **320** may be required at or near the roofline depending on the length of the pivot-bar **315** and roofline **106**. For example, for a roofline greater than about 20 feet, greater than about 25 feet, or greater than about 30 feet, it may be necessary to attach the center of the pivot-bar to a roof-penetrating anchor point. Other customizable features described above may obviate use of roof-penetrating anchor points for embodiments which comprise gable-mounted pivot-bars.

The mounting frames previously disclosed may be incorporated with other components to provide a roof-mountable solar photovoltaic power system. Such systems may comprise one or more solar photovoltaic panels **400** capable of generating electrical power, a power inverter **410** and a power outlet, as depicted schematically in FIGS. 4A, 4B, and 4C. The power inverter **410** may comprise a power source meter and switch, capable of converting DC power to AC power. In

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some embodiments the system is capable of outputting DC power, AC power, or both DC and AC power. In some embodiments the system may comprise a quick-connection point for supplying power. Power may be supplied to electrically-powered devices, the power grid **440**, or external energy storage units **430**. In some embodiments the system includes an internal energy storage system, such as a rechargeable battery, a flywheel, a closed cycle fuel cell, or combinations thereof. The energy storage units may deliver power at a controlled or required rate, and may additionally simultaneously store energy.

In some embodiments the system may comprise one or more snow removing, wiping, and cleaning devices, which may be operated or powered by battery, hand-crank, wind turbine, or other suitable means. Examples of such snow removal devices can be found in co-owned U.S. Patent Application 20110308574 A1 titled "SOLAR POWERED ELECTRICAL GENERATION DEVICE AND RELATED METHODS", the disclosure of which is herein incorporated by reference. Such optional snow removing devices **450** are shown in FIGS. 4A-C.

The system may deliver electrical power to an electrical utility grid **420**, depicted schematically in FIG. 4A and FIG. 4B as an electrical utility conductor, through a generated power source meter and switch **410**. The generated power delivery switch **410** is capable of controlling the amount of electrical power from the power source **400** delivered to the electrical utility grid **420**. Some embodiments may also include a secondary power generator **440** to aid in a simulated grid connected system as in FIG. 3D. The purpose of the secondary power generator is to supply grid frequency appropriate for the power source and switch **410**.

Advantages of the solar photovoltaic power systems described herein are realized further realized in their "plug-and-play" capability, wherein prefabricated modular systems can be quickly and efficiently installed on virtually any rooftop and immediately begin delivering or storing power. Examples of such "Plug-and-play" devices can be found in co-owned U.S. Patent Application 20110308574 A1 titled "SOLAR POWERED ELECTRICAL GENERATION DEVICE AND RELATED METHODS", the disclosure of which is herein incorporated by reference.

The invention claimed is:

1. A modular, roof-mounted solar energy apparatus comprising:

a mounting frame having:

a plurality of brackets each having a first arm connected to a second arm at a connection point wherein the plurality of first arms form a first plane and the plurality of second arms form a second plane; and

one or more solar panels;

wherein the apparatus is securably positioned with the one or more connection points proximate a roof edge, such that at least one of the first plane or second plane is planar with a first roof surface, and wherein one bracket of the plurality of brackets further comprises a gable arm attached to the first arm and the gable arm is substantially planar with a roof gable.

2. The apparatus of claim 1, wherein the gable arm is anchored to the roof gable.

3. The apparatus of claim 1 wherein the apparatus is capable of maintaining its position on a roof in winds up to about 105 mph.

4. The apparatus of claim 1 further comprising a snow removal device.

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5. The apparatus of claim 1 further comprising an adhesive located at least between one or more of the mounting frame and the first roof top and the mounting frame and the roof gable.

6. The apparatus of claim 5 wherein the adhesive comprises a coefficient of thermal expansion between or equal to one of the coefficient of thermal expansion of the roof surface and the coefficient of thermal expansion of the mounting frame.

7. The apparatus of claim 1, further comprising one or more of a power inverter, a power outlet, or an internal energy storage system comprising one or more of a rechargeable battery, a flywheel, and a closed cycle fuel cell.

8. The apparatus of claim 1 wherein the length of one or more of the first arm and the second arm, or the gable arm is adjustable.

9. The apparatus of claim 1 wherein one or more of the connection points comprise a hinge.

10. The apparatus of claim 1, wherein the gable arm is further attached to the second arm of the same bracket.

11. The apparatus of claim 1, wherein one bracket of the plurality of brackets further comprises a plurality of gable arms, forming a third plane.

12. The bracket of claim 11, wherein the plurality of gable arms are attached to the first arm of the same bracket, the second arm of the same bracket, or both.

13. The bracket of claim 11, wherein the one or more solar panels are positioned on the first plane, the second plane, the third plane, or combinations thereof.

14. The apparatus of claim 11, further comprising one or more perpendicular cross beams connected to the plurality of first arms, the plurality of second arms, or combinations thereof.

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15. The apparatus of claim 1, wherein the apparatus comprises two gable arms, and each of the two gable arms are attached to the first arm of two different brackets of the plurality of brackets.

16. A modular, minimal penetration rooftop mounting frame comprising:

a plurality of brackets, each bracket having:

a first arm; and

a second arm connected to the first arm at a connection point;

wherein the plurality of first arms form a first plane capable of accepting a flat panel and the plurality of second arms form a second plane capable of accepting a flat panel, the frame is securably positioned with the one or more connection points proximate a roof edge such that at least one of the first plane or the second plane is planar with a roof surface, and wherein one bracket of the plurality of brackets further comprises a gable arm attached to the first arm and the gable arm is substantially planar with a roof gable.

17. The apparatus of claim 16, wherein the apparatus comprises two gable arms, and each of the two gable arms are attached to the first arm of two different brackets of the plurality of brackets.

18. The apparatus of claim 16, wherein the gable arm is further attached to the second arm of the same bracket.

19. The apparatus of claim 16, wherein one bracket of the plurality of brackets further comprises a plurality of gable arms, forming a third plane capable of accepting a flat panel.

20. The bracket of claim 19, wherein the plurality of gable arms are attached to the first arm of the same bracket, the second arm of the same bracket, or both.

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